**Article title: Electronic prescribing system design priorities for antimicrobial stewardship: a cross-sectional survey of 142 UK infection specialists**

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**Short running title:** E-prescribing software features for antimicrobial stewardship

**3-5 keywords (very general terms such as 'bacteria' and 'human' and terms already present in the title should be avoided, as should non-standard abbreviations):** CPOE, prescription, E-prescribing

**Synopsis**

The implementation of electronic prescribing and medication administration systems (EPMAs) is a priority for hospitals and a potential component of antimicrobial stewardship.

**Objectives**

This study aimed to identify software features within EPMAs that could potentially facilitate antimicrobial stewardship and to survey practising UK infection specialist healthcare professionals in order to assign priority to these software features.

**Methods**

A questionnaire was developed using nominal group technique and transmitted via email links through professional networks. The questionnaire collected demographic data, information on priority areas and anticipated impact of EPMA. Responses from different respondent groups were compared using the Mann Whitney U test.

**Results**

Responses were received from 164 individuals (142 analysable). Respondents were predominantly specialist infection pharmacists (48%) or medical microbiologists (37%). 59% of pharmacists had experience of EPMA in their hospitals compared to 35% of microbiologists. Pharmacists assigned higher priority to: indication prompt ($p<0.001$), allergy checker ($p=0.003$) treatment protocols ($p=0.003$), drug-indication mismatch alerts ($p=0.031$) and prolonged course alerts ($p=0.041$); and lower priority to a dose checker for adults ($p=0.02$) and an interaction checker ($p<0.05$), than microbiologists. A "soft stop" functionality was rated essential or a high priority by 89% of respondents. Potential EPMA software features were expected to have the greatest impact on stewardship, treatment efficacy and patient safety outcomes with lowest impact on *Clostridium difficile* infection (CDI), antimicrobial resistance and drug expenditure.

**Conclusions**

The survey demonstrates key differences in health professionals’ opinions of different healthcare benefits of EPMA but a consensus of anticipated positive impact on patient safety and antimicrobial stewardship.

## INTRODUCTION

Antimicrobial resistance (AMR) is a major threat to public health and a significant resource and cost burden on the United Kingdom (UK) National Health Service (NHS).[1] The Chief Medical Officer's 2013 report on infections and the rise of AMR called for action to preserve the effectiveness of existing antimicrobials through antimicrobial stewardship.[1] The 2013 UK Five Year Antimicrobial Resistance Strategy from the Department of Health (DH) also highlights antimicrobial stewardship as one of seven key areas for action and NHS England has subsequently introduced antimicrobial prescribing reduction goals for English hospitals through the Commissioning for Quality and Innovation (CQUIN) programme for 2016/17.[2;3]

In 2012, the UK Department of Health commissioned a study of the potential benefits to staff and patients of greater use of digital and information technology in the NHS and social care.[4] The study report identified four priority actions, one of which was to drive the rollout and use of electronic prescribing (e-prescribing) in secondary care. Implementation of e-prescribing systems in hospitals presents a unique opportunity to improve the quality of antimicrobial prescribing and to facilitate antimicrobial stewardship.[5-10] Evidence for the benefits of antimicrobial stewardship functionality within e-prescribing systems comes from published research studies demonstrating positive impact on outcomes including increased guideline adherence[11;12] and effective initial therapy[13] or reductions in antimicrobial prescribing,[14;15] resistance,[16;17] dosing errors,[8] length of hospital or ICU stay[14;18] and mortality.[12;13;19] However, many of these information systems were created on a small scale in individual hospitals or groups of institutions and few reports cover the full potential range of software features that enable antimicrobial stewardship. Moreover there does not appear to be a recognised standard to guide the specification and commissioning of an optimal e-prescribing system that includes the required antimicrobial stewardship functionality appropriate for the challenges that health systems currently face worldwide.[20]

This report presents results from a cross-sectional survey of UK infection specialist health professionals. The specific objectives of this study were: to identify, using the nominal group technique, software features within NHS hospital e-prescribing systems that could potentially facilitate antimicrobial stewardship; to assign a priority to these software features according to the opinions of practising infection specialist healthcare professionals; to identify any differences in priority setting according to professional group, hospital status (teaching or district general) or previous experience of e-prescribing systems; and to communicate research findings to e-prescribing software manufacturers and healthcare policy makers.

## MATERIALS AND METHODS

Two focus group meetings of experienced infection health professionals from a local network of hospitals in the south central region of England were convened in order firstly, to identify software features within existing e-prescribing and medicines administration (EPMA) systems that facilitate antimicrobial stewardship and secondly, to identify additional software features with the potential to facilitate antimicrobial stewardship. The focus groups had representation from six infection hospital pharmacists (three with experience of EPMA systems), two consultant medical microbiologists (one with experience of EPMA systems) and one EPMA analyst. The focus group meeting output was a list of software features to be included in a questionnaire for wider circulation among UK infection specialist health professionals. Following the focus groups, two infection pharmacists designed a questionnaire using SurveyMonkey® software. The questionnaire included 42 questions, which were divided into 4 domains. The first domain collected respondent demographic data including professional group, experience in a specialist role, hospital setting and EPMA experience. In the remaining three domains, respondents were asked to assign a priority to individual software features grouped according to the categories of prescribing alerts/prompts (12 features), active prescription surveillance (11 features) and prescribing trend surveillance (8 features). At the end of each domain, respondents were asked to express their opinion of the anticipated collective impact of the software features from each domain on a number of clinical, microbiological and process outcomes. For the prescribing trend surveillance domain, respondents were asked to prioritise a number of technical aspects of the proposed surveillance reports. Finally, the questionnaire provided a freetext narrative section inviting respondents to suggest additional software features with potential to facilitate antimicrobial stewardship, not mentioned earlier in the survey. The questionnaire was piloted in the local region, predominately with infection pharmacists and one medical microbiologist in October 2014. Feedback from the pilot led to the incorporation of one additional category (work efficiency) to the list of process outcomes. A copy of the finalised questionnaire and covering letter to respondents is available as an online Supplement (S1).

Respondents were advised that participation was voluntary and anonymous, that the questionnaire would take approximately 10-12 minutes to complete and that the results would be disseminated to e-prescribing software manufacturers, policy makers and the clinical infection community. The research team took the decision not to collect personal details of respondent names and employers in order to elicit candid responses; although respondent internet protocol (IP) addresses were collected, identifying responses from the same healthcare organisations. A hyperlink to the online questionnaire was distributed via health professional networks including the UK Clinical Pharmacy Association, the Royal College of Pathologists, the British Society for Antimicrobial Chemotherapy and Public Health England. The online questionnaire was closed in July 2015, 7 months from launch. Table 1 presents a glossary of key terms used in the questionnaire that will be referred to throughout this report.

**Analysis methods**

Questionnaire data were summarised with descriptive statistics and analysed using IBM SPSS v.22 with priority ranking of software features by different groups of respondents compared using the Mann Whitney U test. The respondent groups compared were: specialist pharmacists vs. medical microbiologists; respondents from hospitals with EPMA experience vs. those without; and respondents from teaching hospitals vs. district general hospitals (DGHs). A p-value of <0.05 was considered statistically significant. Finally, the freetext narrative comments were analysed by using a summative approach to qualitative content analysis, grouping responses into common themes according to frequency of reporting.[21]

This research did not require NHS Research Ethics Committee approval for sites in England, Scotland, Wales or Northern Ireland according to the Health Research Authority online decision tool (http://www.hra-decisiontools.org.uk/ethics/).

## RESULTS

### Respondent accountability

Responses were received from 164 individuals from 79 unique IP addresses. Twenty-two response sets were removed from the dataset (11 pharmacists, 6 medical microbiologists, one ID physician, 4 nurses and one trainee) due to failure to complete responses to survey questions beyond demographics. Responses from the remaining 142 individuals from 68 unique IP addresses were included in the analysis. Eleven of these 142 did not complete all sections of the questionnaire and missing data were ignored as they comprised less than 10% of responses.

### Respondent demographics

The demographic profile of the 142 respondents included in the analysis is presented in Figure1. Infection pharmacists comprised almost half of respondents (48%; 68/142) from 39 IP addresses and the majority had at least 5 years' experience in a specialist infection role (47/68). Medical microbiologists represented over one-third of respondents (37%; 53/142) from 35 IP addresses and most had at least 5 years' experience (48/53). Six infectious diseases (ID) physicians responded to the survey and a further six respondents were grouped as other healthcare professionals (medical virologist, epidemiologist, junior doctor, infection prevention nurse, surveillance nurse and a consultant in public health).

Fifty-two per cent of respondents were from district general hospitals (DGHs) (71/136 responses) and 45% from teaching hospitals (61/136 responses). Figure 2 illustrates the distribution of experience of EPMA and electronic prescribing systems amongst the questionnaire respondents. Approximately half of respondents (49%; 68/139) reported experience of EPMA or electronic prescribing; 59% of 68 infection pharmacists had experience of EPMA in their hospitals compared to 35% of 52 microbiologists. Forty per cent (56/139) expected implementation of EPMA within 5 years (25 from teaching hospitals and 29 from district general hospitals) but 11% (15/139) did not expect EPMA within 5 years (5 from teaching hospitals and 9 from district general hospitals).

**Prescribing Prompt Software Features**

Table 2 presents survey response data for priority attributed by respondents to 12 software features of EPMA systems grouped within the Prescribing Prompt category. The features considered essential by more than 25% of respondents were: an allergy checking function; a prompt to prescribers to record the clinical indication for prescribing an antimicrobial; a drug interaction check, a “soft-stop” feature to indicate a provisional prescription stop date; a prompt to take a blood sample to monitor drug concentration; and dose checkers for adult and paediatric patients for all antimicrobials.

Specialist pharmacists assigned higher priority to: indication prompt ($p<0.001$); allergy checker ($p=0.003$); and treatment protocols ($p=0.003$) (Table 3). Medical microbiologists assigned higher priority to a dose checker for adults ($p=0.023$) and an interaction checker ($p<0.05$). Respondents from hospitals with EPMA experience assigned higher priority to an indication prompt ($p=0.049$). Respondents from hospitals without EPMA experience assigned higher priority to: restricted antimicrobial block (p=0.011); dose checker for children (p=0.024); and blood level monitoring alert (p=0.033). When responses from teaching hospitals were compared with responses from DGHs, there were no statistically significant differences in opinions of priority for any of the prescribing prompt software features. The majority of respondents considered that both patient safety (60%; 84/140) and ability to deliver antimicrobial stewardship (64%; 89/140) were extremely likely to be improved (Figure 3).

**Active Prescription Surveillance Software Features**

Table 4 presents survey response data for priority attributed by respondents to 11 software features of EPMA systems grouped within the Active Prescription Surveillance category. The features considered essential by more than 25% of respondents were daily reports of: new and ongoing prescriptions for critical antimicrobials; mismatch between prescribed antimicrobials and their corresponding indications; long course lengths; and missed doses.

Specialist pharmacists assigned higher priority to a daily report of mismatch between prescribed antimicrobial and associated indication (p=0.031) and long IV/oral courses (p=0.041) (Table 3). Respondents from hospitals with EPMA experience assigned higher priority to: a daily report of newly-prescribed critical antimicrobials (p=0.015); and a daily report of any newly-prescribed antimicrobial (p=0.024). When responses from teaching hospitals were compared with responses from DGHs, there were no statistically significant differences in opinions of priority for any of the active prescription surveillance software features. The majority (>50%) of respondents considered that both patient safety (30%; 71/135) and ability to deliver antimicrobial stewardship (31%; 80/134) were extremely likely to be improved (Figure 4). Two respondents expressed the view that an improvement in outcomes was extremely unlikely: reduction in expenditure on drugs; and a reduction in risk of *Clostridium difficile*.

**Prescribing Trend Surveillance Software Features**

Prescribing trend surveillance reports as a software feature were generally considered by respondents to be of lower priority compared with prescribing prompts and active prescription surveillance, with only two software feature rated as essential by more than 25% of respondents; reports of trends in point prevalence (proportion of patients prescribed an antimicrobial at a specific point in time); and reports of trends in missed doses (Table 5). There were no statistically significant differences in opinions of priority for prescribing trend surveillance software features between specialist pharmacists and medical microbiologists, nor between respondents with or without EPMA experience. Respondents from DGHs assigned a higher priority to the report of trends in proportion of stat doses where administration was delayed software feature (p=0.034) (Table 3). At least two-thirds of respondents considered that the prescribing trend surveillance group of software features would be likely or extremely likely to have a positive impact on all of the listed clinical, microbiological and process outcomes (Figure 5). More than 90% of respondents anticipated a positive impact on their ability to deliver antimicrobial stewardship.

Respondent opinions of selected technical aspects of prescribing trend surveillance reporting are summarised in Table 6. Respondents expressed equal preference for patient days or patient admissions as an activity denominator. A preference for annual and quarterly reporting intervals was considered to be of very high importance by at least 40% of respondents. Surveillance reports for the whole hospital and by clinical speciality and hospital department were rated of very high importance by at least 40% of respondents, whereas reports by individual responsible consultant physician were considered of lesser importance. Finally, surveillance reports of prescribing and administration of individual antimicrobials, by antimicrobial drug class and by locally defined drug groups such as broad-spectrum agents were rated most highly by respondents with reports grouped by route of administration considered of lesser importance.

**Freetext narrative responses**

Thirty-five respondents recorded narrative responses when prompted to submit suggestions for additional software features not included in the questionnaire and 69 unique statements were identified and grouped into nine common themes, presented in Table 6. Eighteen respondents suggested an interface with other electronic systems for previous and current microbiology investigations and results and for drug and clinical information to guide prescribing. There was an apparent demand for flexibility in reporting software to allow reports to be customised locally but also to generate a standard set of reports for reporting to Public Health England in accordance with antimicrobial stewardship guidance for English Hospitals: Start Smart – Then Focus.[22]

**DISCUSSION**

This is the first survey of UK infection specialist healthcare professionals evaluating opinions of the potential for electronic prescribing software to facilitate antimicrobial stewardship. The two largest health professional groups responsible for antimicrobial stewardship are represented. We estimate an approximate response rate (n=68) of 24% of NHS hospital specialist infection pharmacists and at least 9% of practising UK medical microbiologists.[23;24] Responses were included from 68 unique IP addresses representing up to 36% (68/188) of NHS hospital trusts/boards if the questionnaire was completed from the employing hospital's IP address.[25-28] The responses represented opinions of experienced healthcare professionals, as the majority (79%; 106/134) had worked in a specialist role for more than 5 years. Teaching hospitals are proportionately over-represented compared with

DGHs but there was a good balance of respondents with experience of EPMA systems and those without.

The prescribing prompt software features ranked of highest priority by respondents were allergy checker, interaction checker and dose checker, which are already incorporated as standard functionality in a number of existing e-prescribing systems in NHS hospitals.[29] The response data suggest an unmet need for prescribing prompt software features that are particularly relevant to antimicrobial prescribing such as recording of indication and "soft stop" functionality; that are not routinely incorporated into existing e-prescribing systems. The responses suggest relatively little appetite among UK infection specialists for software features to support restriction of prescribing of selected antimicrobials, possibly reflecting the inter-speciality conflict inherent in such policies, resource implications and the lack of longer-term superiority over persuasive interventions.[30] Priorities for active prescription surveillance software features were divided between an emphasis on patient safety (drug-indication mismatch and missed doses) and antimicrobial stewardship (prescriptions for critical antimicrobials and long course lengths). Reports of new or ongoing prescriptions of any antimicrobial were considered lower priority, potentially reflecting the limited resources available to antimicrobial stewardship teams.[31] While respondents were less likely to rank proposed software features from the prescribing trend surveillance group as essential, all of these software features were considered at least high priority by over two-thirds of the responding clinicians, suggesting a perception of value from longer-term surveillance data for monitoring performance and measuring the impact of prescribing interventions. Opinions of the expected impact of the proposed prescribing prompt and active prescription surveillance software features on patient outcomes, public health outcomes and resource use outcomes were overwhelmingly positive. It is particularly striking that more than 90% of respondents considered prescribing prompt software features and active prescription surveillance features either likely or extremely likely to improve patient safety, corroborated by an expectation of improved treatment efficacy and reduced

*Clostridium difficile* infection. A positive impact of all three groups of software features on their ability to deliver stewardship and efficient deployment of stewardship resources was especially evident from the responses.

We found that pharmacists were more likely to prioritise a prescribing prompt to record indication, which may reflect the uncertainty faced by hospital pharmacists when validating new prescriptions for antimicrobials (for safety and effectiveness) prior to authorising dispensing; and the requirement to audit antimicrobial prescribing for adherence to local treatment guidelines.[22;32] A relative preference amongst pharmacist respondents for a treatment protocol software feature is consistent with the finding that pharmacist respondents also ranked daily reports of drug-indication mismatch a higher priority in comparison to medical microbiologists. We found that medical microbiologists were more likely to prioritise prescribing prompts for dose checking and interaction checking in comparison to pharmacists, perhaps indicating differences in undergraduate teaching and endorsing the value of a multi-disciplinary approach to infection management.

Respondents from hospitals with experience of EPMA systems ranked the indication prompt feature as relatively more important in comparison to those without, suggesting an unmet need amongst existing software systems. We observed remarkable consistency between the priorities assigned to software features by respondents from teaching hospitals and those from DGHs. When technical aspects of surveillance reports were considered, it is of interest that reports by individual responsible consultant physician were considered of lesser importance than reports by clinical speciality or hospital department. This finding suggests a lack of willingness to employ a “name-and-shame” approach to stewardship and may represent a preference for promoting a sense of collective responsibility amongst clinician colleagues. Freetext comments identified strong user demand for an interface with the microbiology laboratory software system to support selection of effective therapy and de-escalation and to facilitate prompt intervention when patients are prescribed potentially ineffective therapy.

This cross-sectional survey was designed in accordance with recommended principles of health professional survey design as far as possible within the available resources.[33;34] However, a shorter questionnaire may have improved the response rate.[33] The exclusion of data relating to address or employer means that we cannot rule out the possibility that multiple responses may have been submitted by the same individuals and it is likely that multiple respondents from the same Trust had an effect on our findings. We were also unable to collect information on non-responders so the respondent sample is likely to be biased towards more motivated individuals who are engaged with quality improvement and/or information technology. Approximately half of respondents reported experience of EPMA or electronic prescribing and this suggests a bias towards hospitals with such systems when compared with a survey carried out by Public Health England in 2014 which reported only 17/76 (22%) of respondent hospitals with e-prescribing for at least one inpatient area.[35] The questionnaire did not specifically elicit a description of the existing software features of EPMA systems currently installed in NHS hospitals but anecdotal evidence from the research team and from professional networks in the UK suggests that software features to support antimicrobial stewardship are extremely limited. Finally, the present questionnaire was primarily distributed by e-mail to members of professional organisations and therefore may not represent the views of non-members.

The target audience for this survey – consultant medical microbiologists and specialist pharmacists – was deliberate, to focus on individuals most likely to be responsible for stewardship within an NHS hospital organisation. However, other healthcare workers also play an important role in antimicrobial stewardship at the individual patient level including junior and senior doctors, nurses, non-medical prescribers and ward pharmacists.[36-41] Inclusion of these professional groups in user-testing at the design stage of EPMA implementation is likely to be critical to the success of the proposed software features. Future surveys focussing on front-line prescribers and medication administrators are critical.

The advent of e-prescribing to NHS hospitals represents a unique new opportunity to engage with healthcare professionals to promote safe, effective and proportionate antimicrobial prescribing and to refresh the antimicrobial stewardship message. It must be acknowledged however that with this opportunity also comes new threats to patient safety from prescribing and administration errors as well as potential de-skilling of healthcare professionals.[42-44] The judicious use of educational prompts may facilitate a sustained change in prescribing behaviour but this must be balanced against the recognised risk of "alert fatigue" and competing priorities for e-prescribing system functionality from other medical and surgical specialities.[45] Successful implementation of the proposed antimicrobial stewardship software features into e-prescribing systems will likely be contingent upon a variety of sociotechnical considerations including seamless integration into the prescribing workflow with minimal time penalties for end-users and full compatibility with existing NHS information technology hardware and software.[43;46]

This survey represents the first attempt to canvas opinion of infection specialists in the UK on the potential for e-prescribing software to support antimicrobial stewardship. The survey results reveal considerable demand for additional software features expressed by the healthcare professionals charged with promoting rational use of antimicrobials and a consensus of anticipated positive impact on patient safety and efficiency outcomes. The survey demonstrates key differences in health professionals' opinions of different healthcare benefits of EPMA and underscores the need for a multi-disciplinary approach to the development of EPMA system specifications. We trust this information will prove valuable to software manufacturers currently developing e-prescribing systems when prioritising software functionality and systems interface development and potentially to healthcare commissioners when drafting e-prescribing system specifications. Finally, we commend this topic to research funders with a view to funding research into the potential benefits and unintended consequences of e-prescribing system functionality designed to support antimicrobial stewardship.


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## TRANSPARENCY DECLARATIONS

None to declare.


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**Table 1. Glossary of key terms used in the survey of opinions of infection specialists on electronic prescribing and antimicrobial stewardship**

| Term | Explanation |
|---|---|
| **Prescribing alert / prompt** | The prescriber will be alerted via a “pop-up” message – an “alert or prompt” – e.g. if attempting to prescribe an antimicrobial which is contra-indicated because of an allergy or a drug interaction |
| **Active prescription surveillance** | Active prescription surveillance refers to the application of surveillance data in real-time for identification of patients currently prescribed antimicrobial therapy. Software features allow prioritisation of patients for intervention by the antimicrobial stewardship team (AST).<br><br>Active prescription surveillance reports would typically include: patient name, date of birth, hospital number, inpatient location in the hospital, drug name, drug dose, start date, stop date (if specified), prescriber and responsible senior physician. |
| **Prescribing trend surveillance** | Prescribing trend surveillance refers to the review of retrospective data relating to antimicrobial prescribing and administration – typically as trends over time. Prescribing trend surveillance allows continuous monitoring of performance for the purposes of controls assurance and for evaluating the impact of stewardship interventions. |
| **Order Sets** | This software feature allows the prescriber to select an infection (e.g. pneumonia, community-acquired, severe) and the system will automatically populate the prescription with the locally pre-defined treatment regimen (single drug or combination of drugs) at standard doses. |
| **Critical antimicrobial** | An antimicrobial may be designated “critical” by a hospital AST according to local priorities – for example, broad-spectrum antimicrobials such as carbapenems or antimicrobials with a narrow therapeutic range such as colistin. A prescriber may be alerted when prescribing a critical antimicrobial with an appropriate locally-defined message containing details of actions required when prescribing. |
| **Restricted antimicrobial** | An antimicrobial may be designated “restricted” by a hospital AST on grounds of financial cost, propensity to predispose to *Clostridium difficile* infection or local decision to reserve for multidrug-resistant infections. Prescribing of restricted antimicrobials requires pre-authorisation by a medical microbiologist or infectious diseases physician (“restricted antimicrobial authorisation”) or prescribing is limited by the prescribing software to senior clinicians (“restricted antimicrobial block”). |
| **Soft Stops** | This software feature allows the prescriber to nominate a date when the antimicrobial prescription should be reviewed with a view to stopping, changing treatment or switching route of administration to oral. After the review date has passed, the drug will remain visible and available to nursing staff to administer but will be prominently highlighted as being past the review (soft stop) date |
| **Blood level monitoring order set** | When a relevant drug is prescribed, the EPMA system will automatically pair the drug prescription with an order for a blood specimen to be taken at an appropriate time post-dose. |
| **Drug-indication** | A mismatch occurs when a prescribed antimicrobial is not appropriate or |

| | |
|---|---|
| **mismatch** | unauthorised for the recorded indication/provisional diagnosis. |
| **Days of Therapy (DOTs)** | One DOT represents the administration of a single systemic antimicrobial on a given day regardless of the number of doses administered or dosage strength. For example, administration of ceftriaxone as 4g once-daily or as 2g twice-daily for one day would both represent 1 DOT. A single patient receiving both vancomycin and ceftazidime during the same day would be recorded as receiving 2 DOTs (1 of vancomycin and 1 of ceftazidime).[47] |
| **Length of Therapy (LOT)** | LOT refers to antimicrobial course length and is the number of sequential days that a patient receives any systemic antimicrobial drug(s), irrespective of the number of different drugs.[47] A prescription of intravenous piperacillin-tazobactam and vancomycin for 2 days followed by oral co-amoxiclav for 5 days corresponds to a LOT of 7 days. |
| **Point Prevalence** | Point prevalence is the proportion of hospital patients active on the EPMA system that are prescribed any antimicrobial at a specific point in time (for example at noon on the first day of each month). |

Figure 1. Demographic profile of respondents: professional group and years of experience in specialist infection role

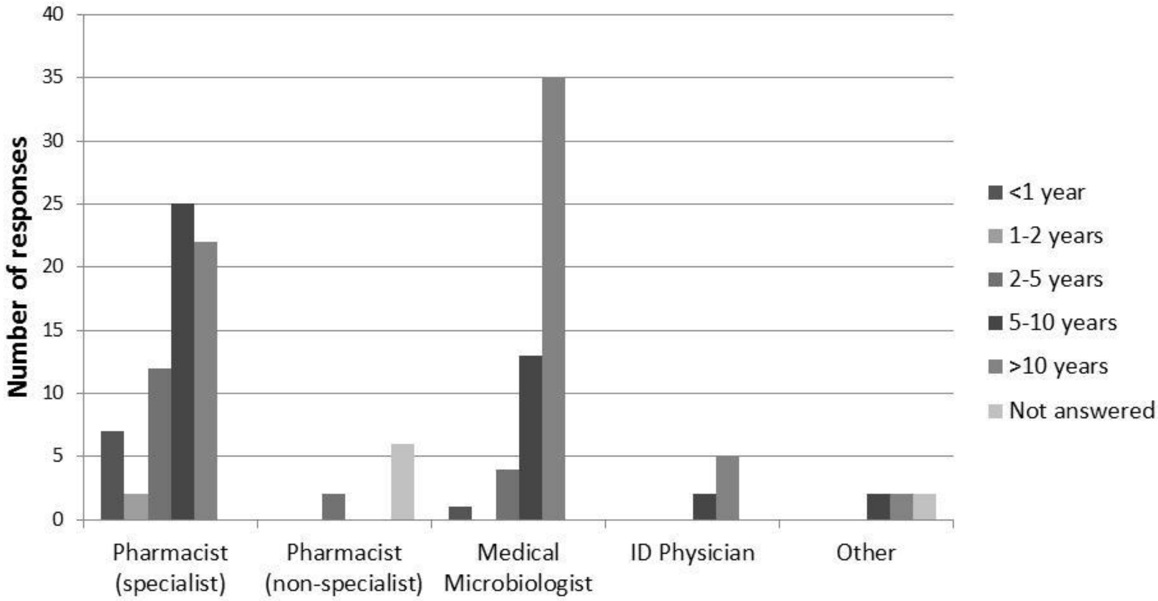

Figure 2. Respondent experience of EPMA and ePrescribing systems (n=139)

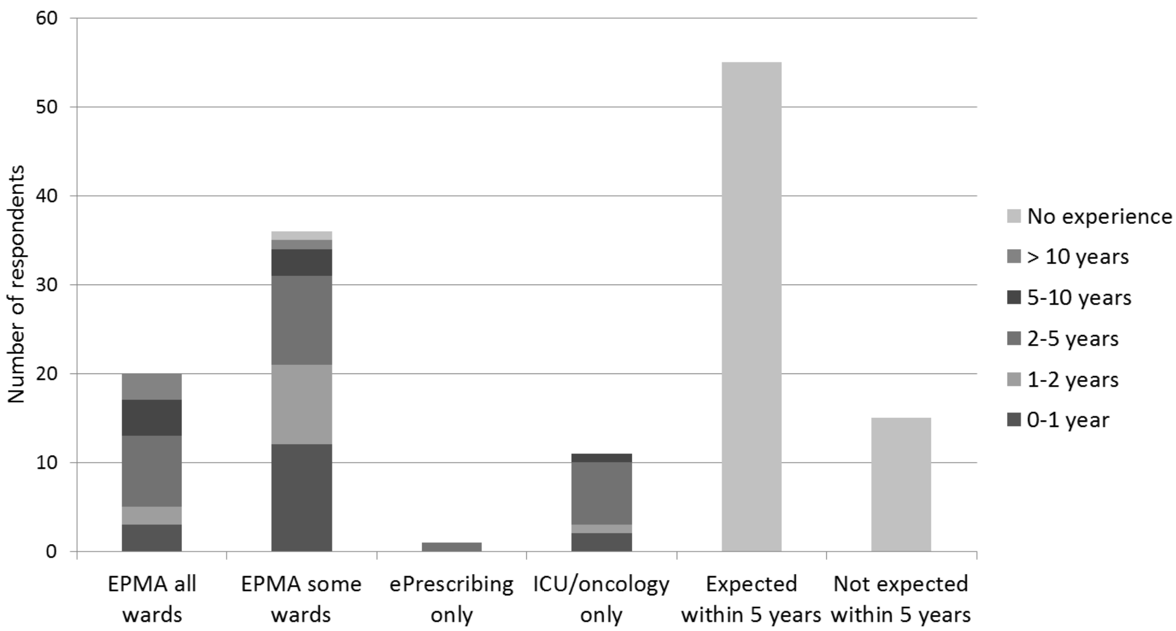

**Table 2. Prescribing Prompt software features ranked in order of respondent-assigned priority**

| Software feature | Number of responses | Essential | High priority | Medium priority | Low priority | Not a priority |
|---|---|---|---|---|---|---|
| **Allergy checker** | 142 | 80.3% | 14.8% | 3.5% | 1.4% | 0.0% |
| **Indication prompt** | 139 | 56.8% | 30.9% | 10.8% | 1.4% | 0.0% |
| **Interaction checker** | 143 | 45.5% | 35.7% | 14.7% | 4.2% | 0.0% |
| **Soft stop** | 141 | 38.3% | 51.1% | 7.1% | 2.8% | 0.7% |
| **Blood level prompt** | 140 | 35.0% | 46.4% | 15.7% | 2.9% | 0.0% |
| **Dose checker (children)** | 142 | 33.8% | 44.4% | 19.0% | 2.1% | 0.7% |
| **Dose checker (adults)** | 141 | 25.5% | 48.2% | 22.0% | 3.5% | 0.7% |
| **Critical antimicrobial prompt** | 141 | 24.1% | 48.2% | 21.3% | 4.3% | 2.1% |
| **Indication order set** | 143 | 21.7% | 45.5% | 25.2% | 4.9% | 2.8% |
| **Blood level order set** | 140 | 21.4% | 39.3% | 29.3% | 9.3% | 0.7% |
| **Restricted antimicrobial require authorisation** | 142 | 18.3% | 25.4% | 30.3% | 17.6% | 8.5% |
| **Restricted antimicrobial block by prescriber** | 140 | 15.7% | 31.4% | 26.4% | 16.4% | 10.0% |

**Table 3. Differences in software feature priority assignment between respondent groups found to be statistically significant**

| Domain / Respondent group | Software feature | Respondent group (% of responses rated essential) | | Mann-Whitney U test p-value |
|---|---|---|---|---|
| **Professional group** | | **Pharmacists** | **Medical microbiologists** | |
| **Prescribing prompts** | Allergy checker | 90% | 69% | p=0.003 (n=68, 52) |
| | Indication prompt | 73% | 39% | p<0.001 (n=67, 51) |
| | Treatment protocols | 28% | 15% | p=0.003 (n=68, 53) |
| | Dose checker (adults) | 16% | 34% | p=0.023 (n=68, 53) |
| | Interaction checker | 34% | 51% | p=0.047 (n=68, 53) |
| **Active prescription surveillance** | Drug-indication mismatch | 35% | 25% | p=0.031 (n=65, 49) |
| | Long IV/oral course | 31% | 24% | p=0.041 (n=65, 50) |
| **EPMA experience** | | **EPMA-experienced** | **Non EPMA-experienced** | |
| **Prescribing prompts** | Indication prompt | 66% | 47% | p=0.049 (n=68, 68) |
| | Restricted antimicrobial block | 12% | 17% | p=0.011 (n=67, 70) |
| | Dose checker (children) | 26% | 39% | p=0.024 (n=68, 70) |
| | Blood level monitoring alert | 24% | 44% | p=0.033 (n=67, 70) |
| **Active prescription surveillance** | Daily report of newly-prescribed critical antimicrobials | 64% | 40% | p=0.015 (n=64, 68) |
| | Daily report of any newly-prescribed antimicrobial | 23% | 16% | p=0.024 (n=64, 68) |
| **Hospital type** | | **Teaching** | **District General** | |
| **Prescribing trend surveillance** | Report of trends in proportion of stat doses where administration was delayed | 28% | 18% | p=0.034 (n=55, 65) |

541 **Figure 3. Respondent opinions of the likely impact of Prescribing Prompt software features**
542 **on clinical, microbiological and process outcomes**

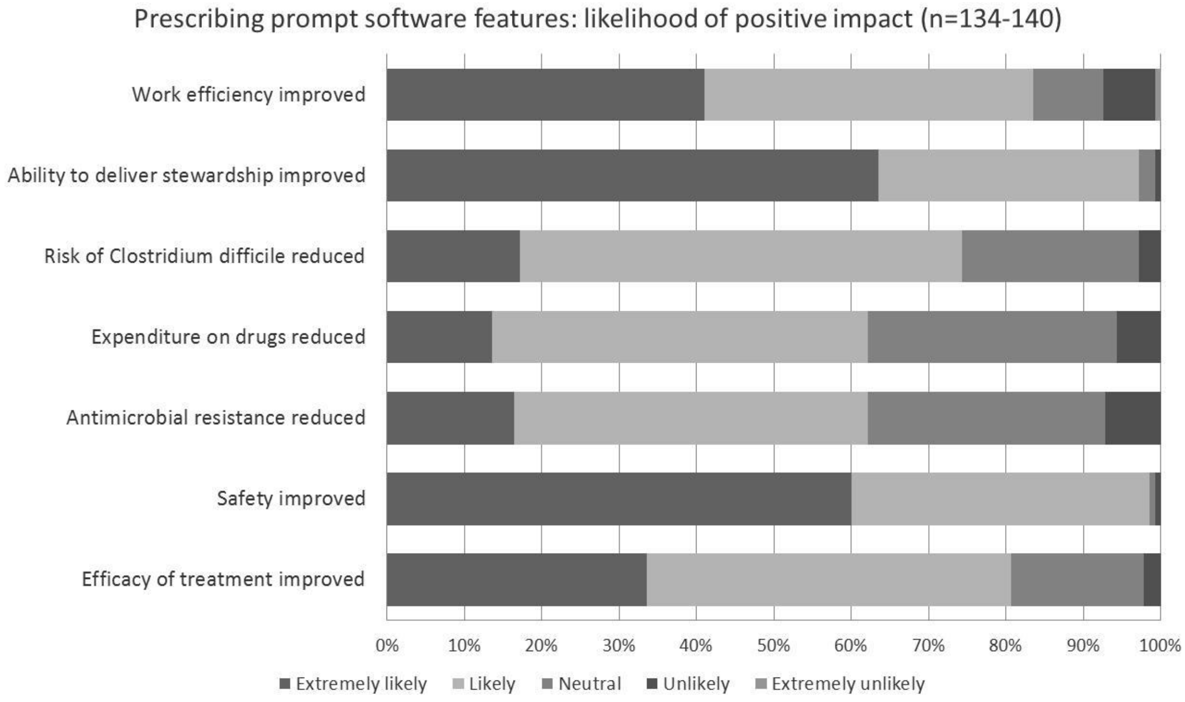


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**Table 4. Active Prescription Surveillance software features ranked in order of respondent-assigned priority**

| Software feature | Number of responses | Essential | High priority | Medium priority | Low priority | Not a priority |
|---|---|---|---|---|---|---|
| New Rx of critical drug | 135 | 51.9% | 41.5% | 6.7% | 0.0% | 0.0% |
| Ongoing Rx of critical drug | 135 | 42.2% | 42.2% | 15.6% | 0.0% | 0.0% |
| Drug-indication mismatch | 134 | 31.3% | 47.8% | 17.9% | 3.0% | 0.0% |
| Long IV/oral course | 135 | 28.9% | 54.8% | 14.8% | 0.7% | 0.7% |
| Missed Abx doses | 132 | 26.5% | 43.9% | 22.7% | 6.1% | 0.8% |
| Long IV course | 132 | 25.0% | 59.8% | 14.4% | 0.8% | 0.0% |
| High-dose aminoglycoside | 133 | 23.3% | 40.6% | 25.6% | 9.0% | 1.5% |
| New Rx for sepsis of unknown origin | 134 | 20.1% | 57.5% | 19.4% | 1.5% | 1.5% |
| New Rx of any antibiotic | 136 | 19.1% | 27.9% | 33.1% | 17.6% | 2.2% |
| Ongoing Rx of any antibiotic | 133 | 13.5% | 30.8% | 36.1% | 15.0% | 4.5% |
| New Rx for diagnosis of interest | 135 | 13.3% | 51.9% | 30.4% | 3.0% | 1.5% |

**Figure 4. Respondent opinions of the likely impact of Active Prescription Surveillance software features on clinical, microbiological and process outcomes**

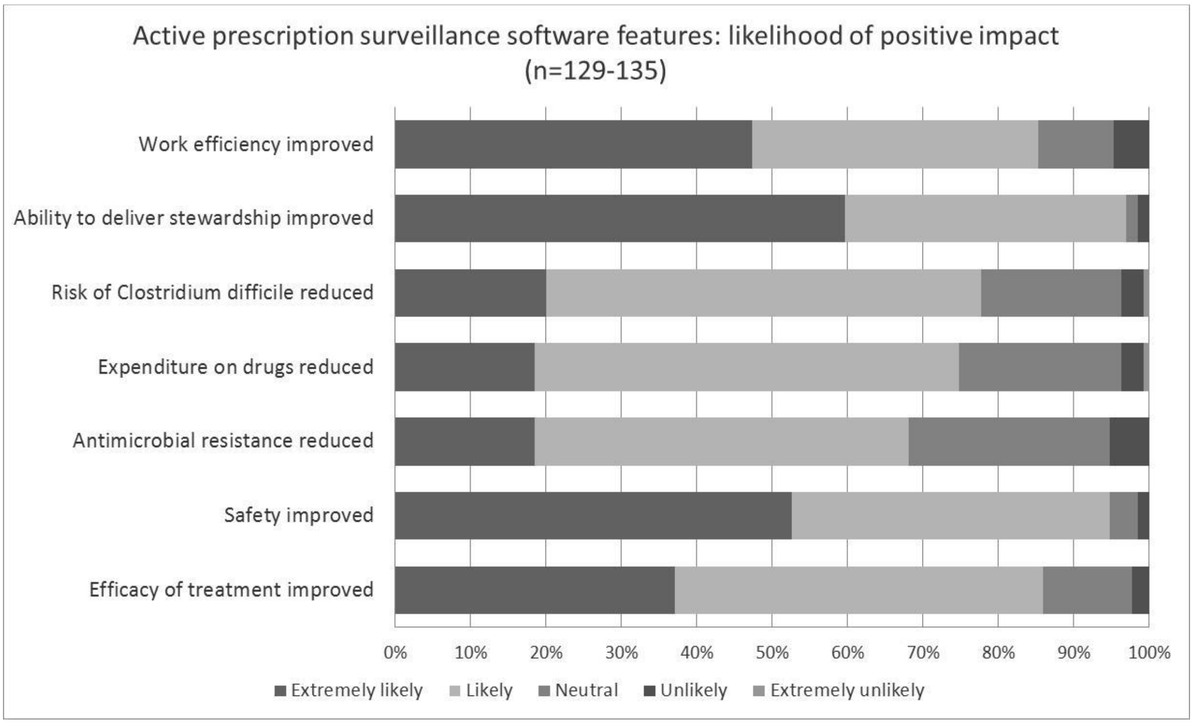
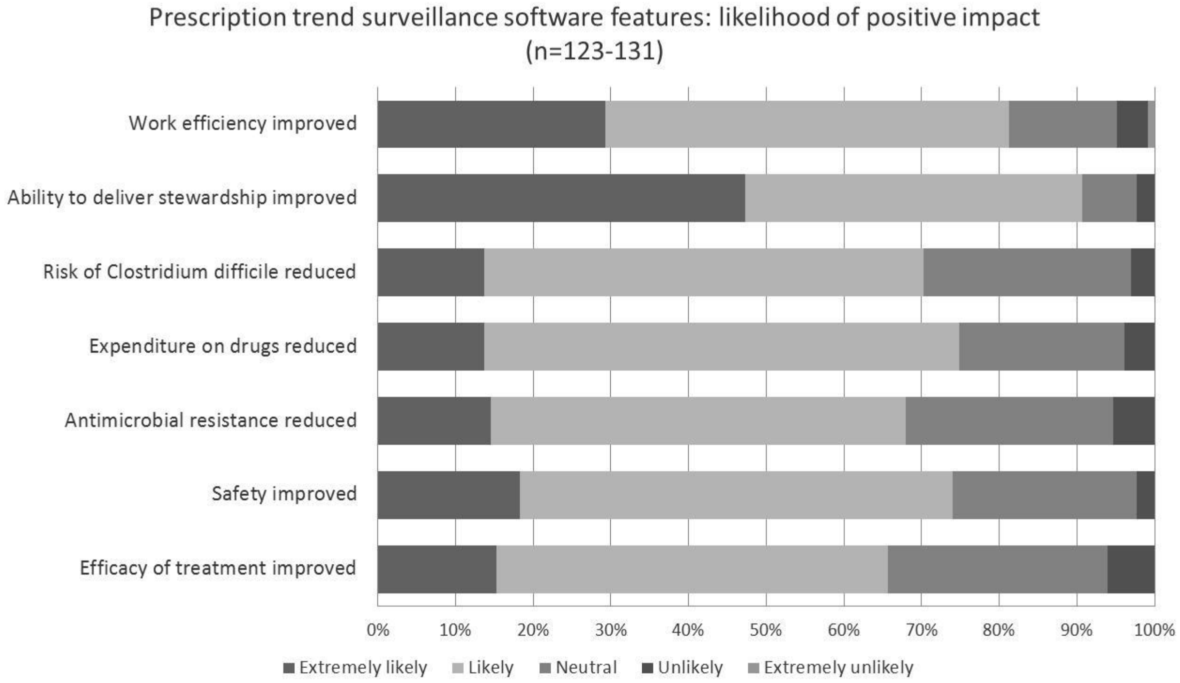


**Table 5. Prescribing Trend Surveillance software features ranked in order of respondent-assigned priority**

| Software feature | Number of responses | Essential | High priority | Medium priority | Low priority | Not a priority |
|---|---|---|---|---|---|---|
| **Trends in point prevalence** | 130 | 29.2% | 44.6% | 23.1% | 2.3% | 0.8% |
| **Trends in missed doses** | 130 | 26.9% | 45.4% | 24.6% | 2.3% | 0.8% |
| **Trends in delayed stat doses** | 130 | 23.1% | 53.8% | 19.2% | 3.8% | 0.0% |
| **Trends in total days of therapy (DOTs)** | 130 | 13.1% | 39.2% | 37.7% | 7.7% | 2.3% |
| **Trends in average length of therapy (LOT)** | 131 | 13.0% | 53.4% | 29.0% | 3.8% | 0.8% |

**Figure 5: Respondent opinions of the likely impact of Prescribing Trend Surveillance software features on clinical, microbiological and process outcomes**



564 **Table 6: Respondent opinions of technical aspects of prescribing trend surveillance reporting**

565 **software features ranked in order of respondent-assigned priority**

| | Response Count | Importance attributed by respondents | | | | |
|---|---|---|---|---|---|---|
| | | Very high | High | Moderate | Some | None |
| **ACTIVITY DENOMINATOR** | | | | | | |
| **EPMA patient days (total number of patients multiplied by number of days)** | 130 | 16.2% | 40.0% | 31.5% | 10.8% | 1.5% |
| **EPMA admissions (new patients)** | 130 | 13.8% | 38.5% | 36.2% | 10.8% | 0.8% |
| **REPORT TIME INTERVALS** | | | | | | |
| **Annually** | 130 | 48.5% | 31.5% | 13.1% | 3.8% | 3.1% |
| **Quarterly** | 130 | 40.0% | 42.3% | 13.8% | 2.3% | 1.5% |
| **Monthly** | 130 | 24.6% | 36.9% | 29.2% | 6.9% | 2.3% |
| **Weekly** | 129 | 7.8% | 20.9% | 27.9% | 28.7% | 14.7% |
| **Daily** | 130 | 4.6% | 15.4% | 22.3% | 26.2% | 31.5% |
| **HOSPITAL SUBDIVISIONS** | | | | | | |
| **Whole hospital** | 129 | 49.6% | 38.8% | 6.2% | 4.7% | 0.8% |
| **Clinical speciality** | 128 | 42.2% | 41.4% | 11.7% | 3.9% | 0.8% |
| **Hospital departments** | 128 | 40.6% | 36.7% | 16.4% | 4.7% | 1.6% |
| **Wards** | 128 | 32.8% | 39.1% | 21.1% | 5.5% | 1.6% |
| **Responsible consultant physician** | 129 | 32.6% | 37.2% | 20.2% | 9.3% | 0.8% |
| **DRUG GROUPINGS** | | | | | | |
| **Individual drugs** | 129 | 48.8% | 36.4% | 10.9% | 2.3% | 1.6% |
| **Drug class (e.g. macrolides)** | 128 | 41.4% | 41.4% | 13.3% | 3.9% | 0.0% |
| **Locally-defined drug group (e.g. broad-spectrum, narrow-spectrum)** | 130 | 40.0% | 38.5% | 16.9% | 4.6% | 0.0% |
| **Antibacterials, antifungals, antivirals, antiparasitics** | 127 | 33.9% | 37.0% | 15.7% | 13.4% | 0.0% |

| | | | | | | |
|---|---|---|---|---|---|---|
| **All antimicrobials** | 130 | 30.0% | 36.9% | 19.2% | 11.5% | 2.3% |
| **By route of administration** | 129 | 24.0% | 40.3% | 24.8% | 8.5% | 2.3% |

**Table 7. Thematic analysis of freetext narrative responses to the question: "Do you have any other suggestions for potential functionality for electronic prescribing and medicines administration systems?"**

| Theme | Frequency | Details of additional user requirements |
|---|---|---|
| Microbiology laboratory system interface | 13 | • Susceptibility testing – prescription conflict ("drug-bug mismatch")<br>• Previous microbiology including healthcare-associated infections |
| Reporting functions | 9 | • Flexibility of reporting – capacity to customise reports locally<br>• Reporting to national standard (Start Smart – Then Focus)<br>• Defined daily doses in addition to DOTs |
| Clinical information system interface | 5 | • Link to guidelines<br>• Drug information: adverse effects, drug administration, drug monitoring<br>• Disease severity scoring systems |
| Restriction systems | 5 | • Authorisation codes<br>• Authorisation by named specialist<br>• System access restricted to trained prescribers<br>• Compulsory recording of indication |
| Additional narrative fields | 5 | • Infection specialist advice<br>• Justification for off-guideline prescribing<br>• Precise nature of drug allergy<br>• Reasons for missed doses |
| Soft stops / review dates | 4 | • Block administration until review<br>• Patient safety of automatic prescription stop |
| Dosing support | 3 | • Dosing by age, weight and renal function |
| Drug history | 3 | • Primary care and previous hospital admissions |
| Stat doses | 3 | • Automatic associated stat dose and appropriately spaced maintenance dose<br>• Stat dose remains visible if delayed |
| Miscellaneous | 19 | |